US-PAT-NO: 5189606
DOCUMENT-IDENTIFIER: US 5189606 A
TITLE: Totally integrated construction cost estimating, analysis, and reporting system
DATE-ISSUED: February 23, 1993
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US-CL-CURRENT: 705/10, 706/923

ABSTRACT: CCMAS is an integrated construction cost generator which may be used to develop costs for construction projects; to analyze and estimate facilities associated with major weapons programs; for administrative, medical and support facilities as well as runway/taxiways; and for developing the life cycle costs for various construction projects. Its uses parametric estimating techniques with a finite field of both codified and unstructured data elements in a unique process which may be accomplished with or without detailed plans or specifications. The system contains more than 900 types of Air Force facilities as well as the quantities of each product required to complete each building type. Estimating tools used include direct costs, life cycle costs and modifiers. Direct costs are further broken down into generic models, a comparative system, and a quantity takeoff (QTO) system. CCMAS has been found to be three times more accurate than conventional architectural and engineering costing techniques.
17 Claims, 31 Drawing figures
Exemplary Claim Number: 1
Number of Drawing Sheets: 31

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Abstract Text - ABTX (1): CCMAS is an integrated construction cost generator which may be used to develop costs for construction projects; to analyze and estimate facilities associated with major weapons programs; for administrative, medical and support facilities as well as runway/taxiways; and for developing the life cycle costs for various construction projects. Its uses parametric estimating techniques with a finite field of both codified and unstructured data elements in a unique process which may be accomplished with or without detailed plans or specifications. The system contains more than 900 types of Air Force facilities as well as the quantities of each product required to complete each building type. Estimating tools used include direct costs, life cycle costs and modifiers. Direct costs are further broken down into generic models, a comparative system, and a quantity takeoff (QTO) system. CCMAS has been found to be three times more accurate than conventional architectural and engineering costing techniques.

TITLE - TI (1): Totally integrated construction cost estimating, analysis, and reporting system

Brief Summary Text - BSTX (4): The present invention relates generally to artificial intelligence,

with an expert knowledge-based system having an inference engine, applied to a Construction Cost Management and Analysis System (CCMAS), and more particularly to a comprehensive cost estimating computer system for construction projects all over the country, and even all over the world.

Brief Summary Text - BSTX (6): Despite the plethora of technological advances, the construction industry has experienced a virtual explosion of cost overruns and claims totaling in the billions of dollars. This is due to the fact that the common method used for estimating the average construction project today is still with paper and pen (or perhaps a computerized spreadsheet to simplify the calculations), cost data manual, and the requirement for enormous amounts of detail prior to beginning the estimate. This method fails to address the numerous concerns facing the construction estimator of the 1990's.

Brief Summary Text - BSTX (9): Estimates produced using the QTO method clearly lack a high degree of reliability and their effectiveness is further diminished as a project becomes more complex. Also, crucial factors, such as risk forecasting and lift cycle cost estimating, are not able to be adequately treated by the traditional, almost anachronistic, method of estimating.

Brief Summary Text - BSTX (11): United States patents of interest include U.S. Pat. No. 4,700,318, to Ockman which discloses a computer system for construction projects such as buildings, bridges, dams, industrial plants, means of transport and the like. The patented system may use an appropriately programmed general-purpose computer or an otherwise similar computer especially dedicated to such purpose. Storage and retrieval of structural information, work activities and other data are conveniently machine-assisted. In Thompson U.S. Pat. No. 4,642,780 a computer system is used in fields such as architecture, space planning, interior design and corporate facility management for efficiently designing and allocating space to the various subdivisions of an organization. The system of this patent operates by gathering answers to a series of questions to the user to elicit information such as project data, identification of departments, available floor space, furniture and equipment, affinities between departments, staffing personnel priorities, etc. In U.S. Pat. No. 4,782,448, Milstein uses a computer 38 as an aid in contract estimating. He is concerned with the building construction trades where there is the necessity to provide accurate estimates of the cost of constructions for use in competitive bidding. In estimating, he takes into account the costs of a vast multitude of structural, plumbing, electrical, heating and other types of purchased equipment and components. Racine in U.S. Pat. No. 4,578,768 describes a computer aided system used in construction, planning, land survey, real estate and many other industries. Aish in U.S. Pat. No. 4,275,449 mentions a Computer Aided Architectural Design (CAAD) system. Cox et al in U.S. Pat. No. 3,927,948 discuss a method and apparatus for designing structures such as industrial plants.

Brief Summary Text - BSTX (12): However, none of the above references teach a comprehensive cost estimating computer system for construction projects all over the country, and even all over the world.

Brief Summary Text - BSTX (15): This invention is directed to an expert knowledge-based

computer system having an inference engine, applied to an integrated construction cost generator which may be used to develop costs for construction projects; to analyze and estimate facilities associated with major weapons programs; for administrative, medical and support facilities as well as runway/taxiways; and for developing the life cycle costs for various construction projects. It uses parametric estimating techniques with a finite field of both codified and unstructured data elements in a unique process which may be accomplished with or without detailed plans or specifications. The system contains more than 900 types of Air Force facilities as well as the quantities of each product required to complete each building type. Estimating tools used include direct costs, life cycle costs and modifiers. Direct costa are further broken down into generic models, a comparative system and a quantity takeoff (QTO) system. The invention has been found to be three times more accurate than conventional architectural and engineering costing techniques.

Brief Summary Text - BSTX (17): CMMAS is the first automated, integrated, and comprehensive construction cost management tool which can be used from project inception through completion. It lets even an unskilled estimator accurately estimate and analyze a facility construction project in less than four hours without plans or specifications. It eclipses the traditional method of designing, measuring drawings, counting pieces, then manually extracting cost data of each piece to create an estimate, and finally analyzing the product; a process that can take a group of skilled estimators up to six months.

Brief Summary Text - BSTX (21): Coalesces the functional UNIFORMAT work breakdown structure with the material/trade CSI work breakdown structure to form a single integrated work breakdown structure for multiple cost estimating methodologies.

Brief Summary Text - BSTX (28): Automatically creates and compares cost estimates using multiple cost estimating techniques operating in a single unique work breakdown structure and drawing from a specially constructed data bases.

Brief Summary Text - BSTX (34): 2. It includes a means according to feature 1 to describe the facility; estimate and analyze the direct construction cost; identify, apply and analyze modifiers and/or adjustments to the facility for location, escalation, method of construction, and schedule of construction; estimate and analyze the contractors overhead and profit; calculate the construction cost or applying the modifiers to the direct cost; estimate and analyze supervision, inspection, and overhead associated with construction management; estimate and analyze design costs; print reports; estimate and analyze the cost to operate, maintain, and repair the facility over its life; and delete the estimate data from the system after it is no longer needed.

Brief Summary Text - BSTX (38): 6. It includes a knowledge base according to feature 5 which contains a construction agency code that links the construction agency used to manage the construction to the cost of supervising and inspecting the construction contractor's work and the cost for additional engineering and design required during construction. It includes a process which shows the user the available codes and allows the user to enter only valid codes. It includes a means of determining the relationship between the agency used and cost of supervising and inspecting the construction contractor's work and the cost for additional engineering and design

required during construction based on historical data, storing the information, and retrieving the information for use in calculating the construction cost.

Brief Summary Text - BSTX (39): 7. It includes a knowledge base according to feature 5 which contains a type of construction code that links the type of construction to the cost of unforeseen conditions during construction. It includes a process which shows the user the available codes and allows the user to enter only valid codes. It includes a means of determining the relationship between the type of construction and cost of unforeseen conditions experienced during construction based on historical data, storing the information, and retrieving the information for use in calculating the facility cost.

Brief Summary Text - BSTX (40): 8. It includes a knowledge base according to feature 5 which contains an escalation code that links the facility to the correct escalation factors. It includes a process which shows the user the available codes and allows the user to enter only valid codes. It includes a means of storing the codes and retrieving the correct escalation factors for use in calculating the construction cost.

Brief Summary Text - BSTX (41): 9. It includes a knowledge base according to feature 5 which contains a design agency code that links the design agency used to manage the design to the cost of designing the facility. It includes a process which shows the user the available codes and allows the user to enter only valid codes. It includes a means of determining the relationship between the agency used and cost of design based on historical data, storing the information, and retrieving the information for use in calculating the facility cost.

Brief Summary Text - BSTX (42): 10. It includes a knowledge base according to feature 5 which contains a type of work code that links the type of work to knowledge bases for determining the facility schedule; facility activities durations; split of work between prime contractors, major subcontractors, and minor subcontractors; and factors used for contractors overhead and profit calculations. It includes a process that shows the user the available codes and allows the user to enter only valid codes. It includes a means of storing the codes and retrieving the information from the appropriate knowledge bases for use in calculating the facility cost.

Brief Summary Text - BSTX (43): 11. It includes a knowledge base according to feature 5 which contains a facility category code that links the facility category to knowledge bases for determining the regression equations to use for the primary and supporting facility costs for the comparative process; the resource distribution factors to use to distribute the costs to the CCMAS-UNIFORMAT System, CCMAS-UNIFORMAT Subsystem, CCMAS unique Assembly, CSI Divisional level of the hierarchy by materials, labor, equipment, for the comparative process; the facility energy use code; and links to the facility type and facility family codes. It includes a process which shows the user the available codes and allows the user to enter only valid codes. It includes a means of storing the codes and retrieving the information from the appropriate data files for use in calculating the facility cost.

Brief Summary Text - BSTX (44): 12. It includes a knowledge base according to feature 5 which

contains a location code that links the facility location to knowledge bases for determining the adjustment factors for labor rates, material prices, and equipment costs; air conditioning load; heating load; workmen's compensation and amount subcontracted; seismic zone; frost penetration; insulation levels; rainfall intensity; degree days; energy costs; contractors' overhead and profit factors; insurance, bonds, permits, and taxes; climate conditions; and productivity factors. It includes a process that shows the user the available codes and allows the user to enter only valid codes. It includes a means of storing the codes and retrieving the information from the appropriate knowledge bases for use in calculating the facility cost.

Brief Summary Text - BSTX (46): 14. It includes a means according to feature 2 to calculate the direct cost of construction including all of the work necessary to build the facility in the location specified using any one or a combination of three estimating methods. It includes a comparative method based on historical costs of projects at the facility type level of the hierarchy with adjustment factors that break the costs down to the Element level of the hierarchy. It includes a series of three generic model methods based on construction practices, engineering equations, expert judgements, and safety codes that determines the requirements at each level of the hierarchy from the facility type to the Element level of the hierarchy. It includes a generic building systems model that covers primary facilities to the five foot line, a series of generic models that cover supporting facilities outside the five foot line; and a specialized series of supporting facility models for a complete airfield. It includes a Quantity Take-Off method that can be used in conjunction with the other two methods or by itself that allows the user to identify the requirements or adjust any of the requirements from the CCMAS unique Assembly level through the Element level of the hierarchy.

Brief Summary Text - BSTX (49): 17. It includes a process according to feature 15 which shows the user all available equations for the particular facility category identified in the project description phase of the process; gets the appropriate parameter from the user; and calculates the results of the equation. It also includes a process that automatically adjust the primary facility costs to account for different seismic conditions, climates, number of stores, subsurface conditions, number of basement levels, exterior closure type, interior layout (open offices vs individual offices), elevators, sprinklers, central plant heating vs boilers, emergency generators, uninterruptible power, shielding for TEMPEST and HEMP, and clean room requirements at the facility type level of the hierarchy based on the location selected during the project description process and answers to questions on applicability of each item to the facility being analyzed. It includes a knowledge base according to feature 7 that contains seismic and climate codes that link the location to an adjustment factor that is used in a process to adjust the results of the equation for seismic and climate effects on the facility construction cost. It includes a means of determining the relationship between the seismic and climate zones and cost of construction based on historical data, expert judgement, and results of analysis from the generic models; storing the information; retrieving the information; and calculating the adjustment to the facility cost. It includes two knowledge bases according to feature 7 that contain questions, answers, and adjustment factors for the remaining adjustments to the primary facility costs. It includes a process that shows the user the questions and all possible answers, gets the user answers, stores the results, and retrieves the appropriate adjustment factor. It includes a means of determining the relationship between the

adjustment items and cost of construction based on historical data, expert judgement, and results from analysis of from the generic models; storing the information; retrieving the information; and calculating the adjustment to the facility cost at the facility type level of the hierarchy.

Brief Summary Text - BSTX (50): 18. It includes a process according to feature 15 that creates regression equations coefficients for the non-linear equation for three general categories of supporting facility work (outside the five foot line of the building) and an overall split of costs between the three major categories of supporting facilities (pavements, utilities, and site improvements) by System level of the hierarchy using historical data. This process includes a means that links the facility type to the proper equations for determining the costs associated with these three major categories of supporting facilities, calculates the costs based on the equation, and stores the results at the CCMAS-UNIFORMAT System level of the hierarchy. In addition to the three general categories of supporting facilities, it includes a knowledge base of construction items at the CSI Division level of the hierarchy to cover work not included in the three general categories of supporting facilities for demolition of buildings and pavement, extensions to aircraft parking aprons, communications ducts, extensions to primary utility distribution systems, special power suppression systems, special system furniture, special power systems, special heating and Air Conditioning systems, and special soil conditions. It includes a process that shows the user the available items groups by the System level of the hierarchy, gets the quantity from the user, and stores the results. It includes a means of determining the cost for these items based on historical data, expert judgement, and results from analysis or from the generic models; storing the information; retrieving the information; and calculating the cost at the CSI Divisional level of the hierarchy.

Brief Summary Text - BSTX (51): 19. It includes a process and knowledge base according to feature 15 that breaks the facility type level costs generated from the regression equations down to the CCMAS-UNIFORMAT System level, the CCMAS-UNIFORMAT System level, and CCMAS unique assembly costs down tot he CSI Division level. It includes a process and knowledge base that further breaks the CSI division level costs down to the Element level of the hierarchy to be completely compatible with the other direct cost methods. It includes a process where these adjustment factors are developed based on historical information, expert judgements, and results of the generic models; storing the information; retrieving the information; calculating the cost at the Element level of the hierarchy; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (60): 28. It includes knowledge bases according to feature 20 which contain the default factors used at the CSI Division, CSI Composite Item Number, and Element levels of the hierarchy. It includes a process that uses a series of algorithms along with the default factors to describe the facility to the user. The process shows the results to the user and stores the results. It includes a means of determining the relationship between the requirements at one level of the hierarchy and the next higher level parameters based on historical data, building safety codes, expert judgement, and engineering principles; storing the information; calculating the cost at the Element level of the hierarchy; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (65): 33. It includes knowledge bases according to feature 29 which contain the default factors used at the CSI Division, CSI Composite Item Number, and Element levels of the hierarchy. It includes a process that uses a series of algorithms along with the default factors to describe the facility to the user. This process shows the results to the user and stores the results. It includes a means of determining the relationship between the requirements at one level of the hierarchy and the next higher level parameters based on historical data, building safety codes, expert judgement, and engineering principles; storing the information; <u>calculating the cost</u> at the Element level of the hierarchy; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (74): 42. It includes knowledge bases according to feature 34 which contain the default factors used at the CSI Division, CSI Composite Item Number, and Element levels of the hierarchy. It includes a process that uses a series of algorithms along with the default factors to describe the facility to the user. This process shows the results to the user and stores the results. It includes a means of determining the relationship between the requirements at one level of the hierarchy and the next higher level parameters based on Air Force and FAA regulations, historical data, building safety codes, expert judgement, and engineering principles; storing the information; <u>calculating the cost</u> at the Element level of the hierarchy; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (81): 49. It includes a means according to feature 2 to <u>calculate the direct cost</u> for the contractors overhead and profit including all of the work necessary for the contractor to manage the workforce in the location specified using any one or a combination of three estimating methods. It includes a comparative method based on historical overhead and profit requirements of projects at the facility type level of the hierarchy with adjustment factors that break the costs down to the Element level of the hierarchy. It includes a generic model method based on construction practices, engineering equations, expert judgements, and safety codes that determines the requirements at each level of the hierarchy from the facility type to the Element level of the hierarchy. It includes a Quantity Take-Off method that can be used in conjunction with the other two methods or by itself that allows the user to identify the requirements or adjust any of the requirements from the CCMAS Assembly level through the Element level of the hierarchy.

Brief Summary Text - BSTX (82): 50. It includes a comparative method according to features 49 based on historical projects at the facility category level of the hierarchy with adjustment factors that break the costs down to the CSI Division level and distribution factors that further break the cost out at the Element level of the hierarchy for mobilization <u>cost; bidding climate for competition</u>; availability of manpower, materials, and equipment; weather effects on constructing the building; project complexity; working conditions; workmen's compensation; and amount subcontracted. It includes a series of knowledge bases and algorithms that link the project direct cost, type of project, location, and working conditions to the contractor overhead and profit requirements. It includes a means of determining the relationship between the information known about the project and the contractor overhead and profit costs based on historical data and expert judgement; storing the information; applying the factors; and storing the results for use by the other processes.

Brief Summary Text - BSTX (87): 55. It includes a series of knowledge bases according to features 52 and 54 which contain a location code along with an altered hierarchy path and factors that is linked to the facility location specified in the project description and the direct cost to determine the bond, insurance, tax, workmen's compensation, and permits requirements by prime contractor and major and minor subcontractors. The process gets the adjustments from the knowledge base, makes the adjustment, and shows the user the new path and factors. It includes a means of determining the relationship between the location and bond, insurance, tax, workmen's compensation, and permits requirements by prime contractor and major and minor subcontractors based on historical data and state and country requirements; and storing the information.

Brief Summary Text - BSTX (88): 56. It includes knowledge bases according to feature 51 which contain the default factors used at the CSI Division, CSI Composite Item Number, and Element levels of the hierarchy. It includes a process that uses a series of algorithms along with the default factors to describe the facility to the user. This process shows the results to the user and stores the results. It includes a means of determining the relationship between the requirements at one level of the hierarchy and the next higher level parameters based on historical data, building safety codes, expert judgement, and engineering principles; storing the information; calculating the cost at the Element level of the hierarchy; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (90): 58. It includes a process according to feature 2 that takes the data from the previous four processes and produces the estimated cost of construction for the time and location specified for the expected cost and the standard deviation about the expected cost based on the information in the project definition modifier. It uses a process that includes the application of the Tchebyscheff Inequality model to calculate an expected cost at 50% confidence along with a high cost at 95% confidence based on the information provided in the project definition section of the modifiers and a series of algorithms that identify the correlation between the various components of construction costs. It includes a means of determining the correlation between the various cost components based on historical data, expert judgement, and engineering principles; storing the information; calculating the expected cost, standard deviation, and 95 percent confidence cost; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (91): 59. It includes a process according to feature 2 which produces several analysis reports that allow the user to compare two estimates at the Facility Category level for direct cost and each modifier for total cost, scope, and unit cost; at the CCMAS-UNIFORMAT System, CCMAS-UNIFORMAT Subsystem, CCMAS Assembly, or Line Item Level by Resource Element; and allows the user to combine facilities to form programs to compare program differences for individual facilities, by year, by appropriation, by location, and by project.

Brief Summary Text - BSTX (92): 60. It includes a means according to feature 2 to calculate the cost to operate, maintain, and repair a facility over its life. It uses a series of knowledge bases and algorithms to generate quantities at each level of the hierarchy from the Facility Category level down to the Element level with the project description information, the direct costs, and modifiers. It includes a process that shows the user the results and allows the user to modify the default

factors calculated and automatically follow the hierarchy structure based on the default factors or user modification. It includes the capability to easily change the factors and algorithms at any level because of new methods and automatically incorporate those new features into the process without having to modify any other parts of the process.

Brief Summary Text - BSTX (93): 61. It includes a knowledge base according to feature 60 which contains the default factor used to escalate the construction, operations, maintenance, repair, energy, and cleaning costs based on year, type of cost, and region of the world. It includes a means of determining the relationship between the projected cost at future times and the cost type and region of the work based on historical data, Department of Energy projections, expert judgement, and Department of Defense projections; storing the information; calculating the time value of the cost at the Element level of he hierarchy; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (95): 63. It includes series of knowledge bases according to feature 60 which contain the link between amount of time maintenance is deferred and the change in cost for maintenance, repair, and operations; life expectancy of the building components; and energy use of the building components by CSI Composite level of the hierarchy. It includes a process that identifies each facility component by its usage in the building based on whether it is used as a dynamic exterior, dynamic interior, transport exterior, transport interior, static exterior, or static interior item to determine the effect of deferred maintenance on the item by how it is used in the building. It includes a means of determining the relationship between deferred maintenance and the cost to operate, maintain, and repair items; their life expectancy; and their energy usage by how the item is used in the facility based on historical data and expert judgement; storing the information; calculating the effect of deferred maintenance; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (96): 64. It includes series of knowledge bases according to feature 60 which contain the link between the facility CSI Composite level of the hierarchy, how the item is used in the facility, and the operations, maintenance, and repair requirements and life expectancy for the item. It includes a means of determining the relationship between the construction item and cost to operate, maintain, and repair the item over its life and its life expectancy based on historical data, trade associations, government agencies, manufacturers recommendations, and expert judgement; storing the information; calculating the costs; and storing the results for use by the other process in CCMAS.

Brief Summary Text - BSTX (97): 65. It includes a series of knowledge bases and algorithms according to feature 60 that determines the cost for the facility by CSI Component level of the hierarchy by linking all of the processes in the Life Cycle Cost module together along with the cleaning cost and financing information input by the user and the construction cost calculated in other section of CCMAS. It includes a process that calculates the cost for each component based on all of the variables input by the user accounting for energy use, building schedule, deferred maintenance, location, life expectancy by component, salvage value, discount rate, and escalation rates to determine the total life cycle cost for the facility. It includes a process that shows the user

the default cleaning requirements and financing information, allows the user to select alternative, stores the information, and uses it in several reports available to show the results of the process or to compare LCC analyses for two facilities.

Drawing Description Text - DRTX (14): FIG. 12 shows the Calculate Construction Costs Section;

Drawing Description Text - DRTX (15): FIG. 13 shows the Life Cycle Cost Model; and

Detailed Description Text - DETX (7): 1. General. CCMAS is a totally integrated process designed to estimate and analyze the life cycle cost of facilities anywhere and anytime. The process is set up in a series of eight sections or steps as shown in FIG. 1 (comprising FIGS. 1a & 1b). The process is further broken down into a series of modules under each section. The system was designed to be able to add modules to each section to enhance the overall system capability. However, the addition of new or improved capabilities in one section does not require modifications to the other sections. All sections use the new capabilities automatically. The overall process starts with describing the project (2.0); then estimating and analyzing the direct cost (10.0 through 18.0); identification of modifiers or adjustments to the project for location, time, and other features (20.0); estimating the contractors overhead and profit (30.0, 32.0 and 34.0); calculating the construction cost or applying the modifiers to the direct cost (40.0); printing reports from the first five sections (50.0); estimating and analyzing the life cycle costs (60.0), and deleting the estimate data from the system (70.0). CCMAS uses knowledge bases stored in tables as factors for algorithms, to select more specific knowledge base from another table, and to store user input to the process. Additionally, CCMAS organizes the analysis by a building hierarchy structure. Following is an overall description of how the knowledge base tables are organized and the CCMAS Hierarchy structure.

Detailed Description Text - DETX (22): a. Comparative Process. This section (FIG. 3, comprising FIGS. 3a & 3b) requires the least amount of user input and time to execute. It uses historical information or information developed from the other process as a comparison to estimate a facility's cost. This process starts with costs at the facility level of the CCMAS Hierarchy and uses factors to break these costs down to the CCMAS-UNIFORMAT System, CCMAS-UNIFORMAT Subsystem, CCMAS Assembly, and CSI Division, then distributes the costs to the element level. The primary source of data used by this module is historical costs of actual executed projects. This historical cost is used to develop regression equations and cost adjustment factors. Additionally, the generic models and QTO processes described in the paragraphs below are used to develop additional cost adjustment factors for this process that are not readily available from historical cost information. Following is a description of how the knowledge bases are created for this process and how they are used.

Detailed Description Text - DETX (33): (4) Comparative Facility Adjustment Factors Tables. There are three tables used to adjust the common facility costs to account for different conditions and construction requirements. These adjustment factors are developed along with a series of questions and answers for the user to make the selection. There are five sets of adjustment factors. The factors are developed from a detailed analysis of construction requirements and their cost for

different conditions. Hundreds of facility cost estimates were analyzed to develop these factors. The factors are normalized to typical Air Force construction. For example, a typical Air Force building has its heat supplied from within the building, therefore, heat supplied from a central plant is a negative adjustment because it will cost less for heat exchanges vs boilers. This factor is just for work within the five foot line of the building, therefore, cost differences for work outside the five foot line are handled as part of the supporting facility analysis. Following is a description of what each of these five sets of adjustments cover:

Detailed Description Text - DETX (40): (5) Comparative CSI/Resource Distribution Factors Table --T101. To maintain the consistency of all estimating systems, the costs developed are all broken down to the Element level of the CCMAS Hierarchy. This table breaks all of the comparative costs down to the Element level by CSI Division. These factors are developed by family category code based on an analysis of actual projects. The comparative process takes the costs developed from T103 and the adjustment factors and produces line item quantities (T324) and costs (T330) using the factors from T101.

Detailed Description Text - DETX (42): (7) Comparative Input/Output Tables. There are several tables used by the model to store the user selections and output from the model and to edit user input. Additionally, the final step in the process is to calculate the direct cost. The calculation consists of multiplying the line item quantities stored in table T324 by the appropriate costs from tables T106, T165, or T330. The results are stored in table T319 with a summary of CSI Division stored in table T348. Following is a list of the additional tables used by this model:

Detailed Description Text - DETX (43): b. Generic System Models (GSM). This section (FIG. 4, comprising FIGS. 4a & 4b) uses a series of knowledge bases and algorithms to accomplish a full Quantity Take Off for a building without plans and specifications. The output from this module is a complete list of items at the Element Level of the CCMAS Hierarchy. All the user has to input is just the building type, total size in square feet, and location. The model starts at the Facility level of the CCMAS Hierarchy and breaks the building down using algorithms and factors throughout the CCMAS-UNIFORMAT System, CCMAS-UNIFORMAT Subsystem, CCMAS Assembly, Composite, and Element levels of the CCMAS Hierarchy. The user is given the opportunity to edit the default factors at each level. The cost data is at the composite or element level of the CCMAS Hierarchy. These models cover a wide range of building types and are developed based on actual projects. However, since they work with quantities of items rather than cost until the Element level, the models can and do incorporate current construction methods and materials. For example, when asbestos tiles were outlawed, the model was easily changed to use vinyl tile. The model factors and algorithms chose the amount of tile as before, but, we were able to easily change the item selected to vinyl tile at the composite level without having to make any changes to the model. Since the building models are developed based on actual historical project data, they are also used to assist in the development of the Comparative Data Base Tables on resource distribution factors (T101) and building adjustment factors (T167). Following is a description of each knowledge base, how it is developed, and how it is used by the models:

Detailed Description Text - DETX (47): (4) GSM Building System Parameter Defaults Table--

T182. This table contains the default parameters used with the building system algorithms in the next paragraph to determine the initial building system values. There are over 150 parameters per building type in this table. Some of the default parameters include floor to floor height, exterior door density, exterior window area, superstructure type, functional space areas, etc. These initial defaults are used with the building system algorithms to describe the building to the user. The user can then override any of the defaults to tailor the building to their project. These defaults were developed based on an analysis of existing Air Force construction for each facility type. For example, the default value for the Floor to Floor Height above grade for an administrative facility is 14 feet and 15 feet for a medical facility. The parameters were also chosen so each model can be used for several different facility types. There are two types of parameters used throughout the model. They are overall building parameters and functional space parameters. Overall building parameters are used for parts of the building that are the same throughout the building such as the exterior closure, superstructure, heating generation system, etc. Functional space parameters are used for parts of the building that are different depending on what that part of the building is being used for. For example, floor covering, wall finishes, electrical outlets, heat distribution system, etc. will vary in a building depending upon what that functional space is being used for. Some functional spaces are open office area, computer rooms, closed office area, surgical rooms, radiology, dining rooms, etc. Table T182 contains the initial default factors for the functional spaces for items such as partition densities, plumbing fixtures, interior windows, interior finishes, etc. Again, these initial defaults are used with the building system algorithms described below to describe the building to the user.

Detailed Description Text - DETX (55): The model uses an algorithm to compute the value, then the user can either accept the value or provide their own value. The only exceptions to this process are the initial parameters of facility type, Gross Floor Area, and location. These are required from the user. As can be seen from the above algorithm, the calculations are accomplished in a specific order because previous values are used in several algorithms. These algorithms are based on engineering equations and Air Force construction criteria. This example is an engineering equation that take the ratio of this building dimensions to the data base value to determine the initial value for the footprint. The actuation selection of which algorithms are necessary was based on an extensive analysis of building costs by building systems to determine what are the cost drivers for a building.

Detailed Description Text - DETX (57): (7) GSM Building Subsystem Algorithms. These are a series of over 500 algorithms used to calculate parameter values for the Subsystem level of the CCMAS Hierarchy. For example, the algorithm for Basement Excavation (System 01--Substructure, Subsystem 04) is as follows:

Detailed Description Text - DETX (68): (13) GSM Assembly Category Algorithms. These are a series of algorithms used to calculate parameters values for the Assembly Categories. These algorithms are set up for either total building calculations of for Functional Space area calculations. The actual algorithm is the same. The difference is whether the model gets a total building parameter value or a functional space parameter value. Following is an example of the algorithm:

Detailed Description Text - DETX (73): (15) GSM Assembly Algorithms. These are a series of algorithms used to calculate parameters value for the Assemblies. These algorithms are set up for either total building calculations or for Functional Space area calculations. The actual algorithm is the same. The difference is whether the model gets a total building parameter value or a functional space parameter value. These algorithms operate just like the Assembly Category Algorithms. Following is an example of the algorithm:

Detailed Description Text - DETX (78): (17) CCMAS Line Item Algorithms. These are a series of algorithms used to calculate parameters values for the QTO Line Items. The results are stored in table T324. These algorithms operate just like the Assembly Algorithms. Following is an example of the algorithm:

Detailed Description Text - DETX (83): (19) Generic System Model Input/Output Tables. There are several tables used by the model to store the user selections and output from the model. Additionally, the final step in the process is to calculate the direct cost. The calculation consists of multiplying the line item quantities stored in table T324 by the appropriate costs from table T106. The results are stored in table T319 with a summary by CSI Division stored in table T348. Following is a list of the additional tables used by this model:

Detailed Description Text - DETX (90): (4) SF Assembly Algorithms. These are a series of algorithms used to calculate the assembly quantities. The algorithms are based on engineering equations. Following is an example of one of the algorithms used to calculate the amount of excavation required in normal soil for a Large Pipe Arch: ##STR1## L=Model Quantity--Length of Pipe ID=Inside Diameter of Pipe

Detailed Description Text - DETX (104): (8) CCMAS Line Item Algorithms. These are a series of algorithms used to calculate parameters values for the QTO Line Items. The line items are stored in table T324. These algorithms operate just like the CCMAS Assembly Algorithms. Following is an example of the algorithm:

Detailed Description Text - DETX (109): (10) Supporting Facility Model Input/Output Tables. There are several tables used by the model to store the user selections and output from the model. Additionally, the final step in the process is to calculate the direct cost. The calculation consists of multiplying the line item quantities stored in table T324 by the appropriate costs from table T106. The results are stored in table T319 with a summary by CSI Division stored in table T348. Following is a list of the additional tables used by this model:

Detailed Description Text - DETX (113): (2) RT Earthworks Quantities Table--T134. This table contains the default dimensions for excavation for different terrains and airfield load type. It includes lengths, widths, slope, cut and fill, and undercut factors developed from engineering analysis and Air Force regulations. The model uses this data with the Runway/Taxiway algorithm to calculate the amount of excavation required.

Detailed Description Text - DETX (128): (17) RT Assembly Algorithms. These are a series of

algorithms used to calculate the CCMAS Assembly quantities. The algorithms are based on engineering equations. Following is an example of one of the algorithms used to calculate the amount of square feet of apron is required without revetments:

Detailed Description Text - DETX (135): (18) CCMAS Line Item Algorithms. These are a series of algorithms used to calculate parameters values for the QTO Line Items. The line items are stored in table T324. These algorithms operate just like the CCMAS Assembly Algorithms. Following is an example of the algorithm:

Detailed Description Text - DETX (139): (19) Runway/Taxiway Model Input/Output Tables. There are several tables used by the model to store the user selections and output from the model. Additionally, the final step in the process is to calculate the direct cost. The calculation consists of multiplying the line item quantities stored in table T324 by the appropriate costs from table T106. The results are stored in table T319 with a summary by CSI Division stored in table T348. Following is a list of the additional tables used by this model:

Detailed Description Text - DETX (142): (1) CCMAS QTO Line Items--Table T106. This table is the main cost knowledge base for the CCMAS models and QTO system. It contains over 40,000 line items. Each line item is either a composite with the associated element level costs or just the element level cost for an item. For example, line item 033111165 used in the WBS description in paragraph 1.b. above, is at the composite level of the CCMAS Hierarchy. The item describes all of the labor, material, and equipment required and the cost for each. The cost of this item is at the element level of the CCMAS Hierarchy. However, line item 180909060 used in the example in paragraph 3.d.(15) above is at the element level of the CCMAS Hierarchy. This item just describes the cost required for labor. Because of the linkage between the CCMAS line items in this table with other CCMAS tables, the process to update the line items is designed to keep the integrity of the system. The update process involves obtaining the data from the over 100 sources used, reformating all of the data to match the CCMAS format, normalizing the data to the same location and point in time, and checking to insure all data referenced by other CCMAS processes is included in this table. The last step is the most critical because it insures CCMAS integrity is maintained. This step is accomplished by a process that checks all other CCMAS tables and processes that reference items in table T106 and reports and items missing from the table. At this point a new item is created to satisfy the linkage required. Several examples of this linkage were shown above in the assembly examples. Several temporary data files are created during this process as shown below. However, the final result is an updated table T106. The following Tables (knowledge bases) are used by this module:

Detailed Description Text - DETX (143): (2) CCMAS Library of Assemblies Table--T108. This is one of the most important tables in CCMAS. This table does three main things. First, it provides the linkage between the CCMAS-UNIFORMAT and CSI Work Breakdown Structures described above. Second, it provides the generic models with the line item quantity factors for the line item algorithms described in paragraph 3.b.(17) above. Third, it combines multiple line items together to make it easier and quicker to estimate and analyze the facility costs. This table is developed based on an extensive analysis of building construction. CCMAS Assemblies are

created to identify all line items required to construct a part of a building. For example CCMAS Assembly 05020402 for a 43/4".times.7'-0".times.3'-0" Fire Rated Hollow Metal Door is build as follows:

Detailed Description Text - DETX (147): (5) QTO Input/Output Tables. There are several tables used by the QTO Module to store the user selections and output from the model. Additionally, the final step in the process is to calculate the direct cost. The calculation consists of multiplying the line item quantities stored in table T324 by the appropriate costs from tables T106, T165, or T330. The results are stored in table T319 with a summary by CSI Division stored in table T348. Following is a list of the additional tables used by this module:

Detailed Description Text - DETX (150): b. Project Definition Modifier. This modifier is used to adjust the project for unknown conditions. It is a risk factor to account for what stage of design the project is in and how much is known about the project by CCMAS-UNIFORMAT system. The project definition modifier factor allows CCMAS to produce a range estimate to show that the project cost could grow to if the worst conditions come true. The modifier consists of a series of algorithms, questions, and factors. The algorithm was developed based on actual project experience to produce an adjustment factor based on the percent of design complete. This adjustment factor is modified by a series of factors that were also based on actual project experience of experts. These factors are tied to a series of questions and possible answers. The questions, answers, and factors are stored in Table T113. This information is used in the calculate construction cost section shown below to produce a range estimate for the project. The Tchebycheff inequality method is used to determine the range. User responses are stored in Table T334. The following Tables (knowledge base) are used by this module:

Detailed Description Text - DETX (156): 5. Create Contractor Modifier. This section consists of three different ways of calculating the contractor overhead and profit for the project. The three methods parallel the three main direct cost methods. They are the Comparative method, a generic model, and a QTO method. The contractor modifier processes account for the construction contractor and subcontractors overhead and profit. This includes mobilization cost; bidding climate or competition; availability of manpower, materials, and equipment; weather effects on constructing the facility; working conditions; etc. Following is a description of the three methods available in CCMAS.

Detailed Description Text - DETX (161): (4) Comparative Contractor Modifier Input/Output Tables. There are several tables used by the model to store the user selections and output from the model. The model applies the percentage calculated to the direct cost modified by the Construction Method Modifier to develop the Contractor Modifier direct cost. This data along with a summary by CSI Division are stored in tables T329, T330, and T349. Following is a list of the additional tables used by this model:

Detailed Description Text - DETX (165): (3) Contractor Modifier Generic Model Parameter Knowledge Base Table--T151. This table contains the default parameters used with the contractor model algorithms and additional data tables in the following paragraphs to determine the initial

contractor modifier component values. There are over 50 parameters by major geographic region in this table. Most of the factors in this table identify whether the item is used by the specified type of work in the geographical region chosen. Additional tables shown below identify how much is used based on other information about the project such as the state, direct cost, etc. For example, this table identifies whether timekeepers are used on a building project in underdeveloped countries. Table T156 shown below shows how many are used per week by dollar value of the project for the prime contractor and major and minor subcontractors. The user can override any of the defaults to tailor the output to their project. These defaults were developed based on an analysis of existing Air Force and commercial projects all over the world. Some of the values in this table actually identify the final value or parameter to be used in the algorithm. For example, the default value for building insurance for developed overseas areas is 2.8% of project cost while the value for underdeveloped overseas areas is 1.8%. The value for the US is 0.0%. Again, these initial defaults are used with the contractor model algorithms and additional data tables in the following paragraphs to describe the contractor's overhead and profit requirements to the user.

Detailed Description Text - DETX (167): (5) Contractor Modifier Generic Model Insurance, Bonds, and Permits Table--T157. These factors all operate on estimated total project cost rather than direct cost. Estimated total project cost is based on the following algorithm:

Detailed Description Text - DETX (168): EPC=Estimated Project Cost

Detailed Description Text - DETX (173): (8) Contractor Modifier Generic Model Parameter Default Table--T156. This table contains over 25 factors by type of work, major geographical region, dollar value of the project, and split between prime/major/minor subcontractors. These factors expand the data in table T151. The factors are developed based on experience. They are used with the algorithms to calculate the initial model values. These factors cover items such as number of field engineers, for the prime, major and minor subcontractors, by dollar value of the project.

Detailed Description Text - DETX (175): STe=Calculated Small Tools Cost

Detailed Description Text - DETX (176): DC3=Calculated Direct Cost

Detailed Description Text - DETX (180): (11) Contractor Modifier Generic Model Assembly Algorithms. These are a series of algorithms used to calculate parameters values for the CCMAS Assemblies Following is an example of the algorithm:

Detailed Description Text - DETX (185): (13) CCMAS Line Item Algorithms. These are a series of algorithms used to calculate parameters values for the QTO Line Items. The line item quantities are stored in table T311. These algorithms operate just like the CCMAS Assembly Algorithms. Following is an example of the algorithm:

Detailed Description Text - DETX (190): (15) Contractor Modifier Generic Model Input/Output Tables. There are several tables used by the model to store the user selections and output from the

model. Additionally, the final step in the process is to calculate the contractor modifier direct cost. While this cost does represent a modifier to the direct cost in section 2, it is still called direct cost to signify the costs are normalized costs at the CCMAS location and time frame. These costs are also adjusted by the modifiers in the previous section during the next section of CCMAS. The calculation consists of multiplying the line item quantities stored in table T311 by the appropriate costs from table T106. The results are stored in table T329 with a summary by CSI Division stored in table T349. Following is a list of the additional tables used by this model:

Detailed Description Text - DETX (193): 6. Calculate Construction Costs. This section (FIG. 12) only requires the user to enter the project identification code to execute. This process takes the data from the previous four processes and produces the estimated cost of construction for the time and location specified. This process uses several of the CCMAS knowledge bases along with a series of algorithms to calculate the construction cost. The results are stored in a series of knowledge bases that are used in the report module to show the results. The calculations accomplished in this module include the application of the Tchebycheff Inequality model to calculate an expected cost at 50% confidence along with a high cost at 95% confidence based on the information provided in the project definition section of the modifiers. Following is a list of the tables used by this module:

Detailed Description Text - DETX (194): 6. Reports. This section is used to produce several preformatted reports. The reports use the knowledge bases created by the calculate construction cost and calculate direct cost modules. The reports get the appropriate data and show it to the user. Following is a list of the preformatted reports available.

Detailed Description Text - DETX (195): a. Cost Analysis Facility Report Summary. This report allows the user to compare two estimates at the summary level for direct cost and each modifier. It compares total cost, scope, and unit cost.

Detailed Description Text - DETX (201): 7. Life Cycle Cost (LCC) Model. This section (FIG. 13) uses a series of knowledge bases and algorithms to accomplish a full Life Cycle Cost Analysis of each individual line item in the facility. The output from this module is a complete list of costs by year for up to a 99 year span at the Composite Level of the CCMAS Hierarchy. All the user has to input is just the CCMAS identification code for the facility. The only restriction for this model is that the facility construction costs must be loaded onto CCMAS. This requirement is necessary because the LCC model uses a mapping scheme between CCMAS line items and the LCC line items. The construction cost portion of the Life Cycle Cost Analysis is accomplished in the previous sections of CCMAS. This section accomplishes the operations and maintenance cost analysis, financing, and economic analysis portions of the LCC analysis. Following is a description of each knowledge base used by the LCC Model, how it is developed, and how it is used by the models:

Detailed Description Text - DETX (202): a. CCMAS QTO Line Item Cost Data--T106. The CCMAS basic line item cost table is used by the LCC module to compute maintenance, repair, replacement, and operating costs. The LCC model was developed to use a percentage of the

original cost for material, equipment and labor to install the item in calculating the LCC cost components. For example, the cost for materials to replace vacuum seals and gaskets on a pneumatic message tube system is 15% of the material cost of the system. Most of the material cost data for the LCC model is directly tied to the construction cost data base. Therefore, as we update the construction cost data base, we are also updating most of the LCC material cost data base. The QTO knowledge base is described in section 2 of CCMAS above.

Detailed Description Text - DETX (208): g. LCC Operations and Maintenance Data Table--T196. This is the main LCC knowledge base table. It contains the LCC line item data. The data in this table includes the LCC item identification, maintenance activity type, frequency, man-hours or labor percent, material percentage or cost, equipment percent or cost, and removal cost. Individual costs or percentages are developed for annual maintenance, cyclic maintenance, and physical damage repair. Data for life expectancy is contained in table T197. This data was developed from extensive surveys of manufacturers, literature, trade associations, universities, hospitals, government agencies with the largest information coming from the Navy Engineering Performance Standards for building maintenance, General Services Administration Buildings Maintenance Management, Corps of Engineers Construction Engineering Research Laboratory survey of building systems, State of Maryland Maintenance and Repair Program, and surveys at several Air Force bases. This data is used to determine the cost by building component, maintenance activity type, and year. Several algorithms are used to adjust the costs based on additional data shown in the other tables for this section of CCMAS.

Detailed Description Text - DETX (209): h. LCC Life Expectancy Table--T197. This table contains the life expectancy for all items that are replaced during the life of a building. This table only contains items that are replaced. The model uses this data to determine replacement times and residual value at the end of the study period. The data is from manufacturers recommendations and experience. The values in this table are modified by deferred maintenance factors in table T186 and energy usage factors in table T187.

Detailed Description Text - DETX (210): i. LCC-QTO Line Item Mapping Table--T198. This table maps LCC line items to QTO line items from the construction cost estimate. Items are mapped by where they are used in the facility. The CCMAS Hierarchy assembly code is used to identify where the item is used in the facility. Therefore, a door that is used in the exterior closure has different maintenance costs than a door that is used in the interior of the building. This table also includes a quantity factor to adjust for different units of measure between LCC and QTO items. For example, the LCC costs for floor tiles may be based on per 100 square feet while the QTO line item is in square feet.

Detailed Description Text - DETX (213): 1. CCMAS Geographical Location Edit Table--T207. This table contains location codes and key information used by every CCMAS module. This table stores information on degree days heating and cooling, and energy rates by region for the LCC Model. The degree days are obtained from weather data. The energy rates are obtained from the Department of Energy. The degree days and energy rates are used along with Table T185 (Component Energy Factors Table), Table T119 (Escalation Modifier Table), Table T213 (Energy

Use Table), the building type, and a series of algorithms to calculate the annual energy cost.

Detailed Description Text - DETX (216): (1) Discount Rate. The user enters a discount rate to be used for the analysis. Standard rates are built into the algorithms, but, the user can override these rates by entering a different rate. The chosen rates are stored in table T401--LCC User Response Table. The rates are used to determine the present value of money in the analysis.

Detailed Description Text - DETX (217): (2) Type of financing used for the construction and operation and maintenance of the facility, if any is used. This includes the rates, points, type of loan, and number of years. This information is stored in table T401--LCC User Response Table. The data is used to calculate the cost of loans per year during the economic life of the project.

Detailed Description Text - DETX (218): (3) LCC Algorithms. Several algorithms are used to determine the costs. Following is the algorithm used to determine the residual value for an item that is replaced during the study period: ##EQU3## CC1=Capital costs of material for the item MLEI1=Material Cost Index for the location

Detailed Description Text - DETX (261): Under the procedure MAINPRC (block 40) there are nine options shown in FIGS. 14c, 14e, 14f & 14g via connector line 41, 1) Create/Edit Project Description (block 410), 2) Create Direct Costs (block 420), 3) Create Other Modifiers (block 430), 4) Create Contractor Modifiers (block 440) 5) Calculate Construction Costs (block 450), 6) Reports (block 460), 7) Delete Estimate Data (block 470), 8) Life Cycle Costs (block 480), and 9) Exit MAINPROC (block 490).

Detailed Description Text - DETX (267): From the Calculate Construct Costs block 450 the system accesses the Absolute Code file ABSMCC (block 4501), which is followed by the Absolute Code file ABSCCC (block 4511). From there, as shown by a connector line 4000, the system returns to the main procedure MAINPRC shown as block 40' in FIG. 14e.

Detailed Description Text - DETX (283): b. The second step is capturing and organizing the engineering rules and heuristics of the construction engineers. CCMAS does this in the work breakdown structure (WBS) provided on the microfiche appendix--table T-215. The key is organizing this data is modeling the interactions among the levels in the work breakdown structure. As different criteria are met at each successive layer of the WBS, a different path may be taken among the knowledge tables described in paragraph a. For example, under certain soil conditions, spread footings are chosen for building foundations, but under different conditions pile foundations are selected. A construction engineer KNOWS the reasons for the changes--CCMAS captures that knowledge in the WBS structure and heuristic rules of iteration. Another more complex example is when a seismic condition is modeled. A construction engineer knows that multiple system in the building must be redesigned or strengthened--the foundations changed, heavier load bearing steel, even down to changing the methods of hanging the steel members. CCMAS models the interactions, through heuristic rules that result in near infinite combinations of paths or decisions, that a construction engineer makes, sometimes without conscious system provide that ARE NOT and CANNOT be modeled with mathematical algorithms. These CCMAS-

organized knowledge bases (i.e., Harmon's definition of an expert system) create a modeling system that "thinks" for itself or, that is, makes decisions normally done by a construction expert. CCMAS allows an inexperienced construction engineer to be as accurate in cost estimating as an "old timer". Reference again Harmon saying expert systems "allow managers to look at problems even when they have incomplete information" (p11)--or the CCMAS, when a construction engineer does not have complete experience.

Detailed Description Text - DETX (288): a. CCMAS Parameters. CCMAS models are based on a hierarchical structure that was determined by the applicants, to adequately represent the requirements of the facility so that reasonable construction costs estimates can be determined based on parameters and facility requirements. The top level of the CCMAS hierarchy structure is the basic parameter level. At this level the total gross square footage of the particular facility, the location, and date of desired construction must be provided. Other parameters which were developed by the inventors can be determined as a function of these basic parameters combined with Air Force design criteria for a particular facility type. The model will divide the total gross floor area for a particular facility into distinct functional space types which are typically associated with that facility. These procedures for this allocation method are modeled based on interpretation by experts of Air Force design criteria as presented in AFM 88-15 and AFR 86-2and as built drawings of actual facilities. When most of the basic facility functional space areas are determined, the facility can be further divided into subsystems, assembly categories, assemblies, and actual quantities of construction material, labor and equipment. The optional parameters are described as follows:

Detailed Description Text - DETX (327): b. Calculation Process for Construction Material, Labor, and Equipment Quantities. The CCMAS models determine facility requirements. Facility parameters are determined as described above. Once parameters are determined, specific subsystem quantities, assembly category quantities and assembly quantities are automatically selected and determined by forward chaining rules designed by construction experts. Once assembly category and assembly quantities are determined, the models can then generate specific material, labor, and equipment quantities that will be required to construct the particular facility. Within each assembly, a knowledge base to set the requirements for specific construction materials and the labor and construction equipment required to install those materials is used to develop the model quantities. The requirements for specific construction material, labor, and equipment can be calculated based on the stored knowledge base. Once particular construction material, labor and equipment requirements are determined, the model can be used to determine construction costs. Costs are mathematical calculations operating on current price data. Although this information could also be used for other purposes, such as procurement, scheduling and other related activities.

Detailed Description Text - DETX (331): Each model is dependent on developing an expert knowledge base. Define the parameters and their corresponding default values. Parameters that define the model must be determined and the "typical" values for those parameters must be defined. Indicate "typical" values for previously defined parameters and/or create new parameters. Define the "Functional Space Areas" (FSAs) for each type of building facility. Where appropriate, standard names should be used for FSAs. Existing CCMAS FSAs can be used if appropriate. The

sum of the FSA floor areas must be equal to the total area of the facility.

Detailed Description Text - DETX (333): Determine the subsystem algorithms. Once the parameters and their corresponding "typical" values are heuristically determined, algorithms (arithmetic equations) using these parameters must be knowledge engineered showing the relationship, interactions, and connectivity among the parameters and the subsystem values for the model.

Detailed Description Text - DETX (338): In a similar fashion, once the assembly category value is calculated, the corresponding assembly factor(s) are determined as follows:

Detailed Description Text - DETX (340): a. If the assembly value is a percent of the assembly category, the value is simply a factor. This type of application works for cases where the quantity of materials to be purchased (or work to be done) is a linear function, i.e., cubic yards of concrete, square feet of gypsum board, linear feet of wire or pipe, etc. For example, in the existing models, ceiling finishes are determined based on factors of the assembly category value for each FSA. In the case of "Open Office Space" in the Administrative facilities Model, the assembly factor for 2'.times.4' suspended acoustical ceiling is 1.0000, which means that one square foot of suspended ceiling is heuristically derived for every square foot of open office space floor area.

Detailed Description Text - DETX (356): CCMAS is an automated cost estimating system developed by the United States Air Force HQ AFESC/DEC to produce high reliability construction and life cycle cost estimates. The system uses multiple cost estimating techniques which operate within a single unique work breakdown structure and draw from an especially constructed data base.

Detailed Description Text - DETX (359): Generic models derive direct costs for material, labor, and equipment based on facility type, size, and location. CCMAS uses algorithms to break down this data into the appropriate types and quantities of systems, subsystems, assemblies, composites, and elements. CCMAS adds and/or deletes assemblies, composites, and elements automatically to account for seismic zone, climate heating and cooling loads, structural features, and architectural features. The CCMAS derived results can be overridden by the user in the generic model or the results copied into the Quantity Take-Off for further tailoring.

Detailed Description Text - DETX (370): Values provided by CCMAS, when a user is unable to provide more specific overriding quantities; the values are based on algorithmic calculations.

Detailed Description Text - DETX (386): 1. Comparative Cost Estimating System

Detailed Description Text - DETX (398): 5. Generic Contractor Modifier Cost Model

Detailed Description Text - DETX (402): 6. Life Cycle Cost Model

Detailed Description Text - DETX (411): e. Calculate Construction Costs, Reports and Delete Data Module.

Detailed Description Text - DETX (417): e. Also data relating to CCMAS, test version 1--Calculate Construction Costs and Reports, Project Description Module, Generic System Model, administrative, medical, runway/taxiway models, QTO model, contractor modifier model and "other" modifiers module.

Detailed Description Text - DETX (451): OMB Circular A-94: Discount Rates to Be Used in Evaluating Time-Distributed Costs and Benefits, March 1972.

Detailed Description Text - DETX (459): For a 50,000 square foot facility, CCMAS reduces the man-hours needed to produce a detailed cost estimate by a factor of 40. CCMAS uses eight man-hours, conventional methods require 320 man-hours.

Claims Text - CLTX (6): inference and control means using said knowledge base file means and said initial input parameters for determining a set of system parameters and default values thereof relating to the facility at a system level, with typical values being defined, means for modifying the system parameters by manual entries;

Claims Text - CLTX (23): 14. In a totally integrated construction cost estimating, analysis, and reporting computer system having a body of procedures organized into sections and a series of modules under each section which automatically selects appropriate algorithms and factors from knowledge base tables to meet functional, physical, and geographic requirements of a total facility which includes a primary facility and associated supporting facilities organized in a work breakdown structure hierarchy;

Claims Text - CLTX (29): a means for analyzing and reporting a facility cost estimate at the total facility, at the facility system level, at the facility subsystem level, at the assembly level; and the elemental level.

Claims Text - CLTX (30): 15. A system according to claim 14 wherein said sections include a section having means for describing a project; a section having means for estimating and analyzing direct construction cost; a section having inference and control means for identifying modifiers or adjustments to the project for location, time, method of construction, and schedule of construction; a section having means for estimating and analyzing a contractors overhead and profit; a section having means for calculating construction cost or applying the modifiers to the direct cost; a section having means for estimation and analyzing the supervision, inspection, and overhead associated with construction management, and a section having means for estimating and analyzing cost to operate, maintain, and repair the facility over its life.

Claims Text - CLTX (39): means for determining the relationship between the type of construction and cost of unforeseen conditions experienced during construction based on historical data, storing the information, and retrieving the information for use in calculating the facility cost;

Claims Text - CLTX (41): means for determining the relationship between the seismic and climate zones and cost of construction based on historical data, expert judgment, and results of analysis from the generic models; storing the information; retrieving the information; and calculating the adjustment to the facility cost;

Claims Text - CLTX (44): means for determining the relationship between the adjustment items and cost of construction based on historical data, expert judgment, and results from analysis of from the generic models; storing the information; retrieving the information; and calculating the adjustment to the facility cost at the facility type level of the hierarchy.